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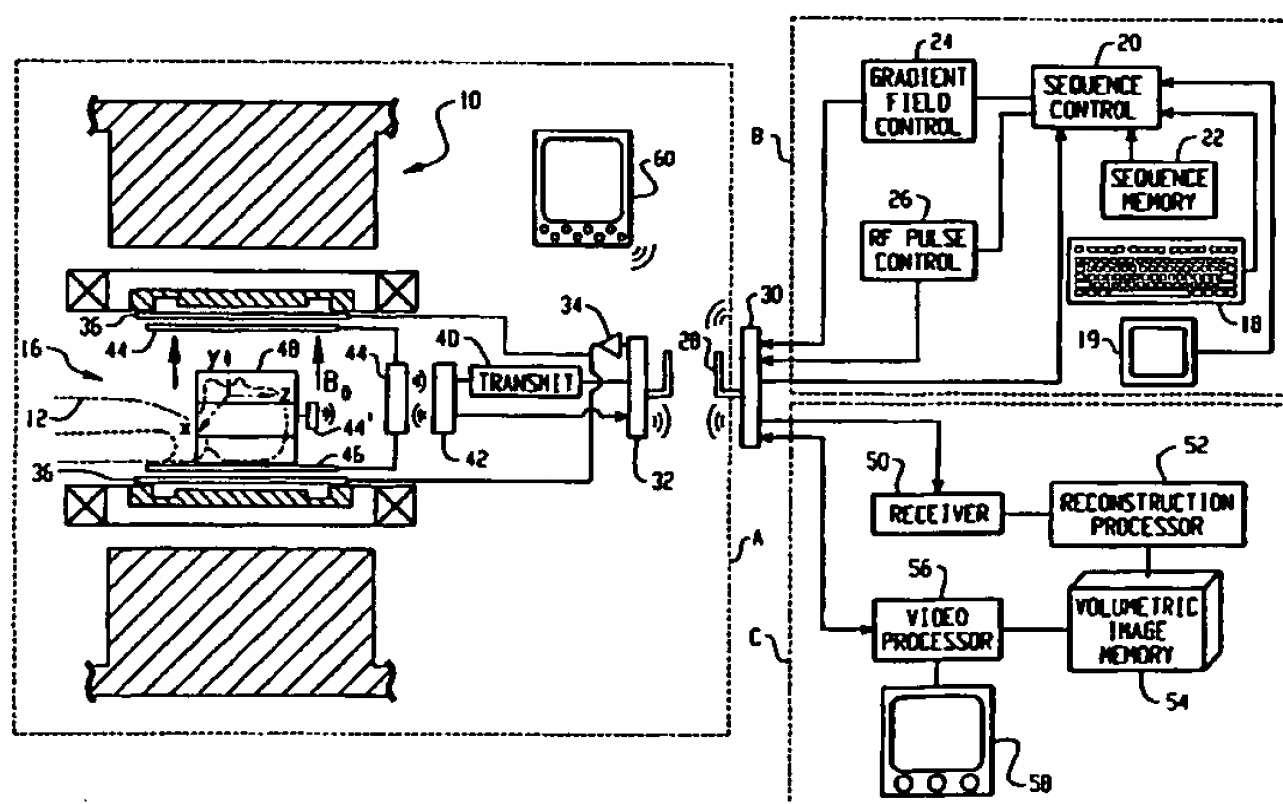
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(54) Title: WIRELESS CONTROLLER AND APPLICATION INTERFACE FOR AN MRI SYSTEM



(57) Abstract: A wireless remote control unit (60) that operates in the radio frequency bandwidth is used for interfacing with a sequence control system (B) and an image processing system (C) from within a magnetic resonance suite (A) in the presence of a magnetic field produced by a main magnet assembly (10). The sequence control system and the image processing system are connected with a first wireless transceiver (30) whose antenna (28) is located within a magnetic resonance suite. The first transceiver (30) communicates with the remote control unit (60) and a second transceiver (32) connected with a transmitter (40) and gradient coil amplifiers (34). Resonance signals received by a radio frequency coil (46) are communicated to the first transceiver (30) by the second transceiver (32) or by a transceiver (46') mounted on the receiving coil. The receiver coil transceiver also engages in a handshake protocol to identify itself.

**WIRELESS CONTROLLER AND APPLICATION INTERFACE  
FOR AN MRI SYSTEM**

**Background of the Invention**

5           The present invention relates to the diagnostic imaging arts. It has particular application in conjunction with wireless communication in a magnetic resonance setting and will be described with particular reference thereto. It will be appreciated, however, that the invention is also applicable  
10 to other modalities including, but not limited to, CT, SPECT, and PET.

          Magnetic resonance (MR) imagers generate high magnetic fields through an imaging region. A typical by-product of the production of this field is a magnetic fringe  
15 field that can extend several meters beyond the physical apparatus. Although the excitation fields are high, the induced resonance signals are weak comparable with ambient television and radio signals. In order to minimize disruption to and interference from the surroundings in an environment  
20 such as a hospital or clinic, the magnets are often built within specially shielded suites to prevent the fringe field from affecting surrounding objects or people.

          As a result, control hardware components for an MR apparatus are placed outside the shielded room. When  
25 controlling the apparatus and recalling images, the operator is outside the suite at the control station. This typically leaves the patient unattended during the scan. In many patients, being alone and in such a constricted area such as the bore of an MR device can cause increased anxiety and  
30 restlessness, ultimately degrading image quality.

          Typically, power and control cables are fed into the MR imaging suite. Cables typically present a problem in that they can introduce radio frequency (RF) disturbances into the imaging volume and receive ambient RF signals. Ultimately,  
35 these RF disturbances manifest as imaging artifacts in final images. Typically, these cables are heavily shielded to prevent interference with radio frequency fields produced by

the MR device, and vice versa, to prevent the RF fields from corrupting information fed through the cables. As a result of shielding, these cables become quite bulky, and present obstacles within the MR suite. This can restrict access to the MR device from wheelchairs, gurneys, walkers, or other mobility limited patients, as well as lessen mobility of the operator, or other support staff about the device.

A further disadvantage of cables in the MR suite is that detuning of the coils is possible. RF receive coils become less sensitive to the resonance frequency, thereby decreasing the signal to noise ratio. In addition, cables can focus RF power onto small portions of the patient, posing potential health hazards.

The present invention provides a new and improved method and apparatus which overcomes the above-referenced problems and others.

#### Summary of the Invention

In accordance with one aspect of the present invention, a magnetic resonance apparatus is provided. A magnet means generates a main magnetic field through a subject in an imaging region. A sequence control means generates magnetic resonance sequences. An RF means receives resonance signals from the imaging region. An image processing means processes the resonance signals into images. A wireless interface means provides wireless communication between systems of the magnetic resonance apparatus.

In accordance with another aspect of the present invention, a method of magnetic resonance is provided. A main magnetic field is induced through a subject in an imaging region. Magnetic resonance is excited and manipulated. Requests to a control console are made with radio frequency signals. Resonance signals are received, demodulated, and reconstructed into an image representation of the subject in the imaging region.

One advantage of the present invention resides in improved mobility for patients and operators around an MR device.

Another advantage resides in the ability of the operator to remain close to the patient during the scan.

Another advantage resides in the reduction of cumbersome material within the medical imaging suite.

Another advantage resides in the ability of the operator to control the MR device from locations other than the control console.

Still further benefits and advantages of the present invention will become apparent to those skilled in the art upon a reading and understanding of the preferred embodiments.

#### Brief Description of the Drawings

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of wireless communication in an MR environment, in accordance with the present invention;

FIGURE 2 is a diagrammatic illustration of a hand held remote interface unit, in accordance with the present invention.

#### Detailed Description of the Preferred Embodiment

With reference to FIGURE 1, an open main magnet assembly 10 which generates a temporally constant main magnetic field, typically denoted  $B_0$ , vertically through an imaging region 16 is disposed in a magnetic resonance suite A. It should be noted that although depicted in conjunction with an open magnet system, the preferred embodiment of the present invention is equally applicable to bore type systems. A subject 12 is disposed on a patient support located in the

imaging region 16 of the magnet assembly 10. The main magnet assembly, 10 is located within a magnetic resonance suite, which is preferably shielded to be impervious to electromagnetic radiation, particularly in the radio frequency  
5 band.

A sequence control system B generates magnetic resonance imaging sequences. A keyboard 18 or touch screen 19 receives operator control commands. A sequence control processor 20 withdraws a selected magnetic resonance sequence  
10 from a sequence memory 22. A gradient field controller 24 produces gradient waveforms in accordance with the selected sequence. Concurrently, an RF pulse controller 26 generates RF pulse patterns in accordance with the selected sequence.

At least an antennae 28 of a first wireless  
15 interface, such as a transceiver 30, is located within the imaging suite A. The wireless interface 30 encodes (preferably digitally) and transmits the gradient waveforms and the RF pulse patterns on a high frequency carrier wave to a second transceiver 32. The second transceiver decodes the gradient  
20 pulse waveforms and communicates them to RF shielded gradient amplifiers 34 which are connected with gradient coils 36. The gradient coils 36 impose gradient fields along the main magnetic field  $B_0$ , thereby spatially encoding the main magnetic field. The second transceiver also decodes the RF pulse  
25 pattern information and supplies RF pulse information to an RF shielded transmitter 40. In one embodiment, the transmitter is connected directly with the RF coil. In the illustrated embodiment, the transmitter is connected to a third transceiver 42 which is in radio communication with a fourth transceiver 44  
30 on an RF coil 46. The RF coil 46 includes a coil identification. A handshaking protocol between transceivers 42 and 44 identifies the coil to the rest of the system. In a system with multiple local or other receive coils, each receive

coil has an identification so the system can identify each coil with a handshaking protocol. The third and fourth RF transceivers 42, 44 share a similar relationship to the first and second RF transceivers 30, 32 as discussed previously. The

5 RF coil 46 transmits the RF pulses into the imaging region 16, exciting and manipulating magnetic resonance in accordance with the selected sequence. The RF receive coil receives the resultant resonance signals which are transmitted to the wireless interface 30 directly or via the second and third

10 transceivers 32, 42. Preferably, the scanner includes the whole body RF coil 46 and a plurality of localized coils, such as head coil 48. The RF coils each include a unique identifier and a transceiver 44'. The transceivers 42 and 44, 44' are preprogrammed with a handshake protocol by which the

15 transceiver 42 interrogates the transceiver 44, 44' to and receives an identification of the coil. The coil information is communicated to the sequence control system to verify that the correct coil is installed and to make any sequence adjustments to customize the sequence to the specific RF coil.

20 In the preferred embodiment, the antenna 28 of first transceiver 30 is mounted to an inside wall of the magnetic resonance suite A. Cables connecting the first transceiver 30 to the antenna 28 are fed through the wall. The second transceiver 32 is preferably mounted adjacent the magnet

25 assembly, with as little cable as possible connecting it to the gradient amplifier 34, the transmitter 42 (in the direct wire embodiment), and other systems of the MR apparatus. Preferably, the first and second transceivers 30, 32 have a line of sight with each other free from any radio-opaque

30 materials in the magnetic resonance suite.

In the preferred embodiment, the first and second transceivers 30, 32 transmit in a higher frequency band than the RF coil 44. In a 1.5 T magnet, hydrogen dipoles (most commonly used for imaging) precess at approximately 64 MHz; in



a 0.75 T magnet, the resonance frequency is approximately 32 MHz. In order to tip these dipoles into the transverse plane, as is common practice, RF pulses containing frequency components close to this precession frequency are synthesized  
5 by the RF pulse controller 26. In the preferred embodiment, the transceivers 30, 32, 42, 44 transmit carrier waves of approximately 2.4 GHz. This ensures that RF signals from the transceivers do not interfere with RF signals used for imaging.

Although about 2.4 GHz is the preferred frequency range, any  
10 frequency above about 500 MHz is acceptable. Frequencies below 500 MHz can begin to interfere with the RF signals used for excitation and manipulation, especially in higher field systems where the dipoles precess with higher frequencies.

Signals from resonating dipoles are detected by the  
15 RF coil 46 or dedicated receive coils 48 and preamplified. The detected resonance signals are encoded and transmitted by the patient side transceiver 44 either to the transceiver 42 or directly to the transceiver 30. The first transceiver 30 receives and decodes the resonance signals and sends the  
20 resonance signals to an image processing system C. A receiver 50 preferably digital, demodulates the resonance signals. The demodulated resonance signals are reconstructed into an image representation of the subject 12 in the imaging region 16 by a reconstruction processor 52. The images are stored in a  
25 volumetric image memory 54, where they remain until needed. A video processor 56 extracts portions needed for viewing, which portions are displayed on a human readable display 58 such as a video monitor, LCD display, active matrix monitor, or the like.

With reference to FIGURE 2 and continuing reference  
30 to FIGURE 1, the preferred embodiment of the invention includes a hand-held remote control interface unit 60. The remote control unit 60 allows the operator to communicate with the sequence control system and the image processor system of the MR apparatus. In the preferred embodiment, the remote unit 60



includes a display 62. From the display 62, the operator is able to observe information regarding the current scan. Such information includes, but is not limited to, elapsed scan time, estimated remaining scan time, selected portions of reconstructed images, available options, etc. Such devices as palm pilots, laptop computers, and the like are contemplated as available embodiments. Cellular phone units are also contemplated.

The remote unit also includes a user input portion 64. This portion allows the operator to relay instructions to the sequence control and image processing systems. Instructions contemplated can be as simple as ordering the commencement or abortion of an imaging sequence, and more complex, such as selecting sequences, adjusting RF pulse bandwidth, or changing the size of the k-space data matrix. Instructions can also be sent to the scanner to start or stop a sequence, adjust patient position, select among receive or transmit coils, establish voice communication with the patient, and the like. The input portion 64 may include a touch screen, keyboard, voice recognition, mouse, or any combination thereof. The input portion 64, of course, is not limited to these devices.

The remote unit 60 includes a transmitter 66 and a receiver 68 that facilitate communication. These two portions are connected to an antenna similar to those found in cellular phones. The 2.4 GHz frequency band does not interfere with the RF pulses which excite and manipulate magnetic resonance or the resultant resonance signals. Moreover, when the device is operated within the shielded suite, it does not interfere with cellular communications in the area. An exemplary realization of such a transceiver is embodied in the Bluetooth™ technology by Ericsson mobile phones.

Also included in the remote unit 60 is a microprocessor 70. The microprocessor 70 processes input from the operator and information transmitted by the first

transceiver 30 for display on the remote unit 60. Optionally, the microprocessor 70 is included elsewhere, remote from the hand-held unit 60.

The remote unit 60 includes a power source. The power source is selected according to the power consumption needs of the remote unit 60. Typical power sources include batteries (disposable or rechargeable), storage capacitors which are charged by AC power or power from RF pulses, and solar cells.

10 In another application of the preferred embodiment, the remote unit 60 is also used in conjunction with peripherals not immediately associated with the MR apparatus. Such devices include ECG machines, respirators, and the like. Communication between the remote unit and the peripheral devices allow the operator to see patient blood pressure, heart rate, and other variables on the remote unit 60. Preferably, each peripheral device has at least a transmitter that transmits directly to the remote unit 60. Optionally, if the microprocessor 70 is not located in the hand held unit 60, then the peripheral device transmits to the first transceiver to process the information transmitted before transmission to the remote unit 60.

In an alternate embodiment, the remote unit is used outside of the imaging suite. In this embodiment, The suite would not be shielded against high frequency RF signals in order to let information to pass into the room.

In another alternate embodiment, the remote unit 60 and transceivers 30, 32, 42, 44, 44' transmit in the infrared spectrum, rather than the radio frequency spectrum.

30 In another alternate embodiment, the remote unit 60 is used in conjunction with a CT or nuclear imaging scanner. In this embodiment, a greater range of radio frequencies are available, as there are no RF imaging pulses with which to interfere.

In another alternate embodiment, the remote interface lacks the input portion 64 and transmitter 66. In this embodiment, the remote unit 60 is a receive only device that displays information as discussed above, but does not accept  
5 user input.

Having thus described the preferred embodiments, the invention is now claimed to be:

1. A magnetic resonance apparatus comprising:
  - a magnet means (10) for generating a main magnetic field through a subject (12) disposed in an examination region (16), the magnet means (10) being disposed in a magnetic resonance suite;
  - a sequence control means (20) for generating magnetic resonance sequences;
  - an RF means (46) which at least receives resonance signals from the examination region (16), the RF means (46) being disposed adjacent the examination region (16);
  - an image processing means (52, 56) which processes the resonance signals received by the RF means (46) into images and manipulates the reconstructed images;
  - a wireless interface means (30, 32) disposed with an antennae (28) in the magnetic resonance suite for wireless communication between (i) at least one of the sequence control means (20) and the image processing means (52, 56) and (ii) at least one of the RF means (46) and a wireless remote control means (60) for communicating between an operator and at least one of the sequence control means (20) and the image processing means (52, 56).
2. The magnetic resonance apparatus as set forth in claim 1, wherein the remote control means (60) includes:
  - a display means (62) for relaying information from at least one of the sequence control means (20) and the image processing means (56) to the operator;
  - an input means (64) for accepting requests from the operator;

an RF transmitting means (66) for transmitting the operator requests to the wireless interface means.

3. The magnetic resonance apparatus as set forth in claim 2, wherein the remote control means (60) further includes:

a radio frequency receiving means (68) for receiving radio frequency signals from at least the wireless interface means.

4. The magnetic resonance apparatus as set forth in claim 3, further including:

a microprocessing means (70) for processing operator input to the remote control means (60).

5. The magnetic resonance apparatus as set forth in one of claims 2-4, wherein the input means includes at least one of:

a keyboard;  
a touch screen; and,  
a voice recognition device.

6. The magnetic resonance apparatus as set forth in any one of the preceding claims, wherein the wireless interface means and the at least one of the remote control means (60) and the RF means (46) communicate with carrier frequencies greater than 500 MHz.

7. The magnetic resonance apparatus as set forth in claim 6, wherein the carrier frequencies are between 2.3 and 2.6 GHz.

8. The magnetic resonance apparatus as set forth in any one of the preceding claims, further including:

an RF transmitting means (40) disposed adjacent the RF means (46);

a radio frequency transceiving means (42) connected with the transmitting means (40) for communicating between the RF transmitting means (40) and the wireless interface means.

9. The magnetic resonance apparatus as set forth in any one of the preceding claims, further including:

additional radio frequency transceiving means (42, 44) for providing a wireless communication pathway between a radio frequency transmitting means (40) and the RF means (46).

10. A method of magnetic resonance comprising:  
inducing a main magnetic field through a subject (12) in an imaging region (16);

exciting and manipulating magnetic dipoles within the imaging region to generate magnetic resonance signals;

receiving and demodulating the magnetic resonance signals;

reconstructing the demodulated resonance signals into an image representation of the patient in the imaging region (16); and

wirelessly communicating at least one of exciting and manipulating instructions, the resonance signals, and image processing instructions with radio frequency signals.

11. In the magnetic resonance imaging system as set forth in claim 10 wherein the communications are digitally encoded on the radio frequency communication signals.

12. The method as set forth in one of claims 10 and 11, further including:

identifying an RF coil (46, 48) with which the magnetic resonance signals are received using a radio frequency communicated handshaking protocol.

13. The method as set forth in any one of claims 10-12, wherein the radio frequencies are greater than 500 MHZ.

14. The method as set forth in any one of claims 10-13, further including:

wirelessly communicating and displaying information pertinent to a current magnetic resonance scan on a remote unit (60).

15. The method as set forth in claim 14, further including:

receiving reconstructed image information with the remote unit (60);

displaying the received image information on the remote unit (60).

16. The method as set forth in any one of claims 10-15, further including:

wirelessly communicating an identification of an RF receiving coil (46, 48) which is mounted adjacent the imaging region (16) to receive resonance signals emanating from the subject (12).



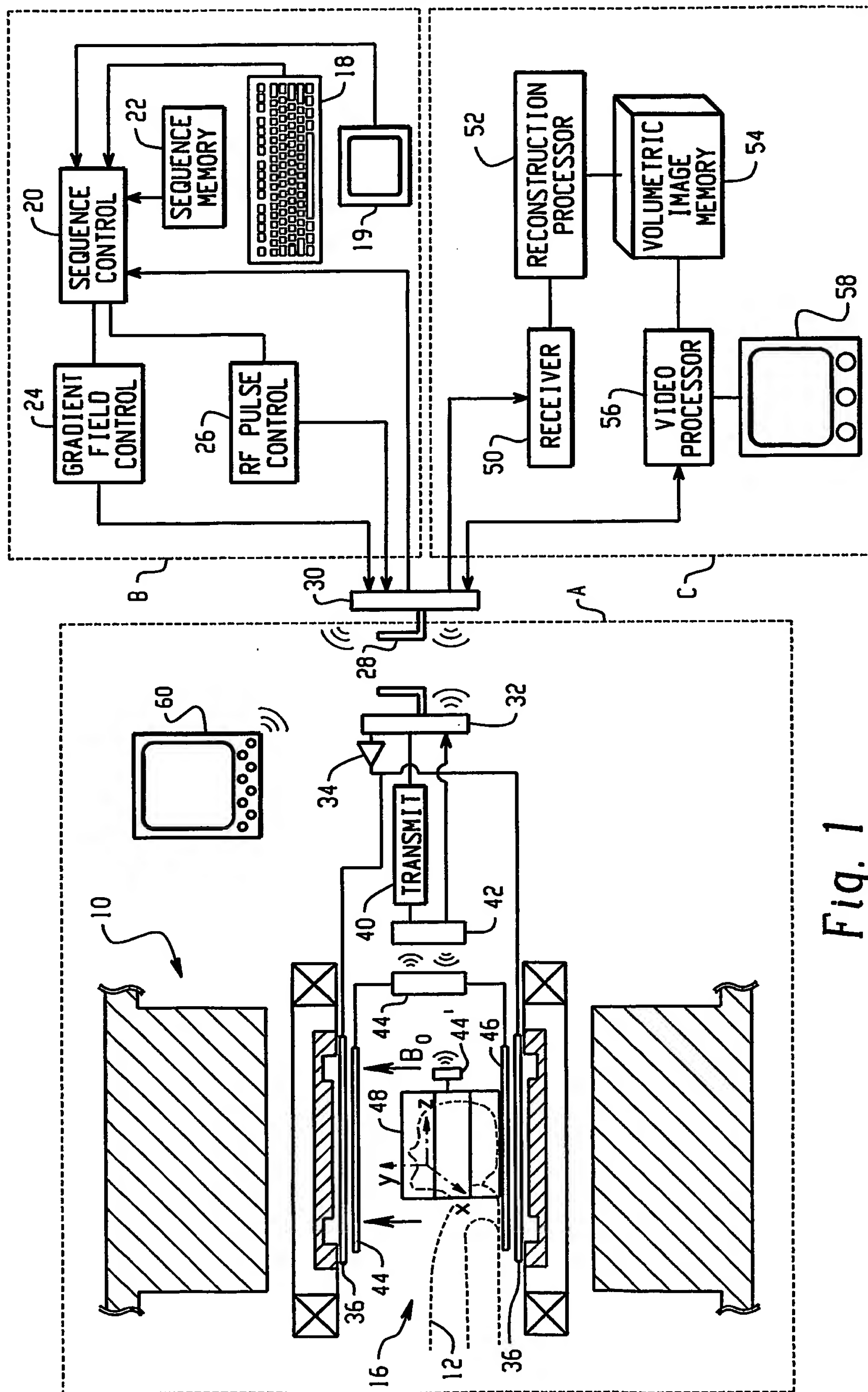


Fig. 1

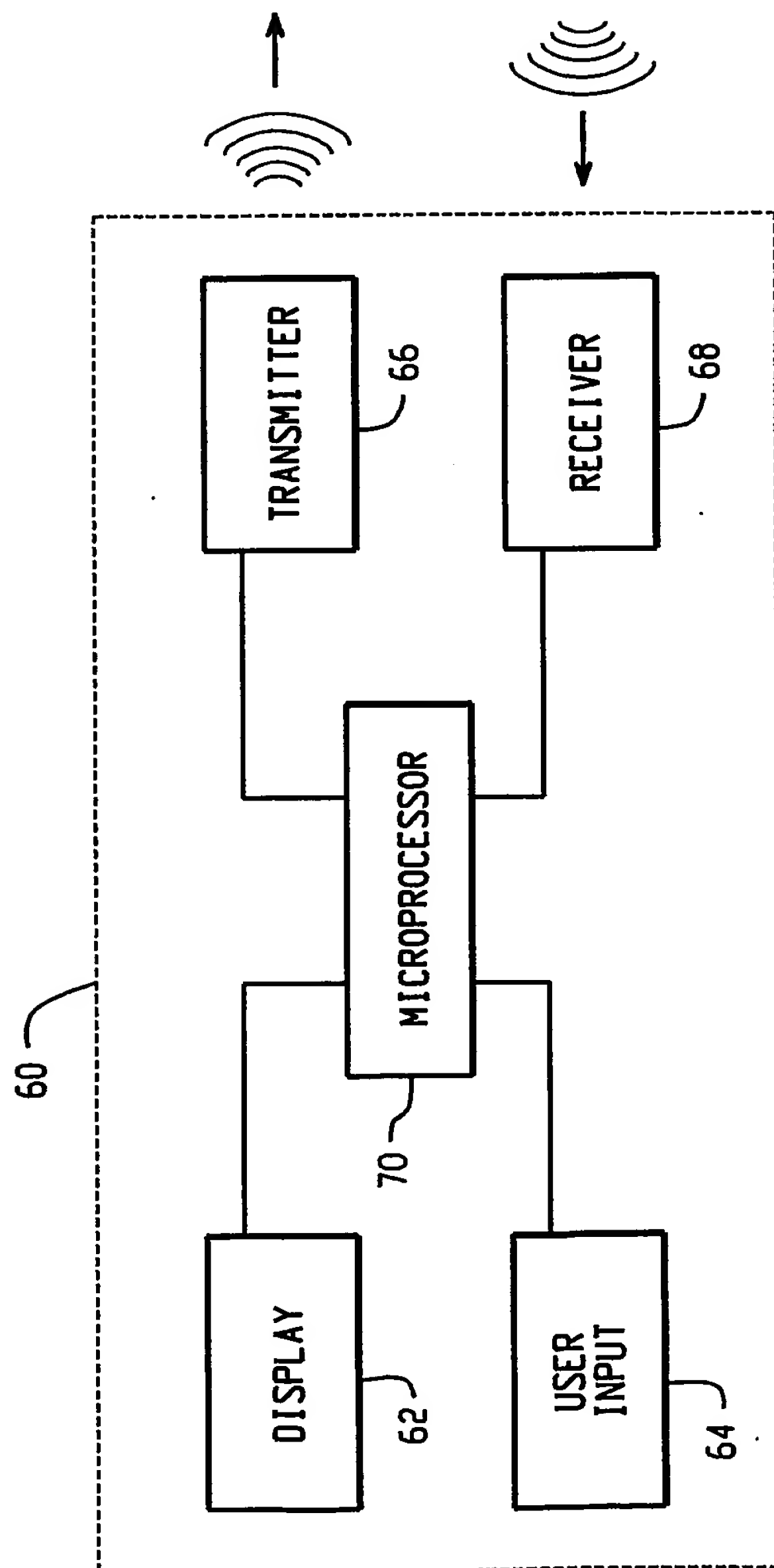


Fig. 2

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 02/32123

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 G01R33/28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC, COMPENDEX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 6 198 285 B1 (KORMOS DONALD W ET AL) 6 March 2001 (2001-03-06) column 1, line 40 -column 2, line 48 column 4, line 32 -column 8, line 57; figures 1,4	1-7,10, 11,13-15
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 02/32123

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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